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Factors Which Affect Shivering in Man During Cold Water Immersion

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ABSTRACT

Six subjects were immersed in cold water (15.15 ± 0.42°C) and were asked to perform two tasks. Shivering elicited by the cold water immersion was attenuated and/or abolished by the mental arithmetic task and in some instances by a voluntary isometric contraction of forearm muscles. Some reasons for these results are discussed.

Key words: Cold water immersion, mental arithmetic forearm isometric contraction, attenuation of shivering.

INTRODUCTION

Shivering consists of synchronous contraction of flexor and extensor muscles and may be thought of as a course adjustment of body temperature (Cooper, 1972). The effector response is mediated via motor nerves whose supraspinal (cerebrospinal and reticulospinal) and peripheral portions (alpha and gamma motoneurons) are known (Hensel, 1973). Proprioceptive activity controls the rhythm of shivering (Perkins, 1945).

Several investigators have probed the mechanisms governing shivering (Downey et al., 1964; Fusco et al., 1961; Lefebre, 1911; Richet, 1893; Sherrington 1924; Thauer, 1970; Uprus et al., 1935) and have variously attributed the principal influence to central or to peripheral thermal stimuli in the initiation of this process. However, factors which attenuate or abolish shivering have also been investigated. Preliminary unpublished findings (Cooper, Lind and Malkinson) showed that shivering appears to be inhibited by certain tasks. This finding could mean that heat production during cold exposure might be adversely affected by such activities. This study was undertaken to investigate whether shivering could be abolished or attenuated by an isometric muscle contraction or a mental arithmetic task.

METHODS

Six subjects were immersed for 11 to 22 min. (average time was 16.5 min.) in water at 15.15 ± 0.42°C. The water covered the shoulders and was continuously and vigorously stirred. The subjects gave informed consent before participating in the study, and each was medically examined as described previously (Cooper et al., 1976). Electromyographic recordings were made using three needle electrodes (Grass Instrument Co., Quincy, Mass.), two of which were inserted in the pectoralis major muscle with the ground needle located over the sternum. The occurrence of shivering was evident by the characteristic changes in the patterns of electrical potentials which were recorded by a Beckman EMG coupler-pre-amplifier system using a pen writing dynograph. The onset of shivering was also observed by visual observation of the subjects. The occurrence of shivering resulted in bursts of electrical activity which varied in both amplitude and frequency. When shivering had been elicited, the subjects were asked to perform two tasks: voluntary isometric contraction of one forearm (40% or 50% of maximum), and to do two sets of mental arithmetic computations. A hand grip dynanometer was used in making the isometric contraction (Clarke et al., 1948). This was suspended over the tank within easy reach of the subject's right hand. The mental arithmetic tasks involved two presentations on a screen, easily visible to the subject, of four consecutive sets of seven randomly arranged numbers. Each number was projected on the screen for 1 sec. and at a given signal, the subject was asked to subtract 2 from each number and give the answer in the correct sequence. The subjects were asked to do the tasks alternately. All subjects were made familiar with both the use of the hand grip dynamometer and the number presentations and practiced each procedure some days before the immersions took place.

RESULTS

The overall results of the subjects who performed the two tasks while immersed in cold water are summarized in Table 1. During the two presentations of the mental arithmetic task, a decrement in shivering was seen in five of the subjects. The sixth subject showed no change during either test. A more variable response was seen after the isometric forearm grip. Three subjects showed a definite decrease in shivering during the 40% of maximum voluntary contraction, whereas only one subject showed a similar response during the 50% of maximum voluntary contraction. Visually violent shaking in the subjects ceased during those tasks in which a decrement in shivering was recorded.

Figure 1 shows a typical response during the mental arithmetic task consisting of three number sets.

An adequate degree of shivering was obtained, and as soon as the subject began the spoken task, which lasted 13, 11 and 10 sec. respectively for the three sets, the shivering was inhibited. When the task was completed, a degree of shivering similar to that of the control period was evident. A comparable pattern occurred during 40% voluntary contraction (40% of maximum). When shivering had been established, the subject was asked

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Table 1. The effect of forearm isometric contraction and mental arithmetic tasks on shivering elicited during immersion in cold water ($15.15 \pm 0.42^{o}C$).

Subject	Shivering	Mental Arithmetic Presentation I	Mental Arithmetic Presentatation II	Forearm Grip 40% MVC	Forearm Grip 50%MVC
M	✓	↓↓	↓↓	↓↓	•
N	✓	↓↓	↓↓	•	↓
O	✓	↓	↓	↓↓	↓↓
P	✓	↓↓	↓	•	•
Q	✓	↓↓	↓	•	•
*R	✓	•	•	↓↓	↓

*female subject

Decrease in shivering	↓↓
Slight decrease in shivering	↓
No change	•
Maximum voluntary contraction	MVC

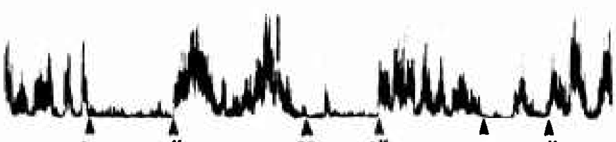

Figure 1. Electromyogram showing shivering during immersion in cold water ($14.3^{o}C$) and its inhibition by mental arithmetic. Mental arithmetic task included consecutive presentation of 4 sets of numbers. Results of 3 sets are shown. Mental arithmetic task times were 13, 11 and 10 seconds respectively (on and off define the period of mental arithmetic).

to hold the 40% voluntary contraction (40% of maximum) for 1 min. A typical response can be seen in Figure 2 where a definite inhibition of shivering can be seen.

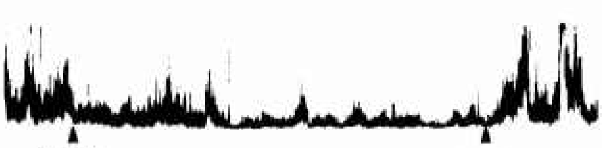

Figure 2. Electromyogram showing shivering and its inhibition by forearm contraction during immersion in cold water ($16.2^{o}C$). Performed task was a 40% maximum voluntary forearm contraction held for 1 minute.

Shivering comparable to that in the control period was re-established once the forearm grip was relaxed.

DISCUSSION

Some factors can attenuate or abolish the shivering response. Some of the findings of this study appear to support the unpublished findings of Cooper, Lind and Malkinson that an isometric muscle contraction could attenuate shivering. In this study, a comparison of two tasks, mental arithmetic and isometric forearm muscle contraction, showed that the mental arithmetic task was more effective in causing a decrement in shivering. Further investigations (Martin and Cooper, 1979) have confirmed and extended this initial finding. Whether this effect implies a greater inhibitory input initiated by the cortical activity, or whether it might simply reflect the fact that the subjects were not sufficiently practised in the use of the dynamometer is now known. One experienced subject who participated in the study, but whose data were excluded because his prescience of the experimental hypothesis might have biased his response, consistently showed an abolition of shivering with a 40% or 50% maximum voluntary contraction. What pathways (secondary or primary) might be involved and how they would influence hypothalmic loci concerned with shivering are unknown. However, some investigations by Stuart (1961) have shown that, in cats, septal stimulation of high intensity could evoke or suppress shivering, and Kaada (1951) has shown that shivering can be inhibited by electrical stimulation of points on the cerebral cortex. This would imply a secondary modulating influence of this area on shivering in contrast to the primary control exercised by the hypothalamus. In view of the plurality of connections of the hypothalamus with various areas of the limbic system and higher brain centers, it would not seem out of order to consider that these areas may be exerting some similar modulating influence on shivering.

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